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p Note #120

MORE ON ANTIQUARK COLLECTORS

Eugene P. Colton

This report describes a recent study I have made into the relative merits of \bar{p} collection schemes that utilize either a lithium lens, a pulsed quadrupole multiplet, or a 5Q36 triplet. It is assumed that the collector follows a source point of radius 0.4 mm and renders the divergent cone of 4.5 GeV \bar{p} into a parallel beam; this beam is then passed through a four-quadrupole telescope and brought to the nominal precooler injection conditions of, e.g., $\beta_x = \beta_y = 10$ m and $\alpha_x = \alpha_y = 0.1$. Table 1 contains the magnetic data for the three considered collectors. The lithium lens pole-tip field is nearly 10 T. The pulsed quadrupoles listed in Table 1 have a pole-tip field of 6 T; the 5Q36 triplet uses existing magnets with a maximum gradient of 19 T/m. The program, TRANSPORT,² was used to obtain the strengths and lengths listed in Table 1. The sinelike trajectories at the collector ends are listed in Table 2. When multiplied by the initial angle, one obtains the final beam size, i.e., $x_f = S_x x_0'$.

The best collector should ideally put as many \bar{p} as possible into the acceptance phase ellipses of the precooler, and into the specified momentum bite. Chromatic aberrations causing effective emittance growth occur in all three collectors. These have been previously discussed.^{3,4} Multiple scattering in the lithium lens also causes real emittance growth. In the remainder of this document, we study the emittance growths for each scheme -- generally for different initial emittances and different $\Delta P/P$. We use the program TURTLE⁵ to obtain the fraction f of started particles that are aberrated out of the initial ellipse phase areas and more generally present the transmission t ($t = 1 - f$). The ray generation is uniform in $x-x'$ and $y-y'$ phase spaces and flat in $\Delta P/P$. We here do not consider other effects such as depth of field due to target length or scattering within the target.

First we consider the 5Q36 collector. An emittance of $5.0 \pi \text{ mm-mr}$ was assumed. This corresponds to a maximum source angle of 12.5 mr. We show the final phase-space ellipses in Fig. 1 for three momentum spreads. The typical butterfly shapes are evident for the nonzero momentum spread cases and significant effective emittance growth is observed. The transmissions drop to 70% and 32.5% for $\Delta P/P = \pm 0.5\%$ and $\pm 2.0\%$, respectively. Apertures limit the maximum emittance to about $7.5 \pi \text{ mm-mr}$ for this system, so no emittance changes were attempted.

Next we compared the lithium lens and pulsed quadrupole collectors systematically for the three initial emittances 5π , 10π , and $20 \pi \text{ mm-mr}$. A momentum spread of $\pm 2\%$ was assumed in all cases. The respective phase-space diagrams are shown in Figs. 2, 3, and 4, respectively. The effects of multiple scattering were introduced in the lithium in 2.5 cm sections. Random deflections up to $\pm 2\sigma$ were applied to \bar{p} trajectories where σ is the rms multiple scattering angle. The transmissions listed on the Figs. 2-4 are collected into Table 3 where we also list the results obtained with no multiple scattering in the lithium lens for comparison.

The results of the present analysis again demonstrate the superiority of the lithium lens collector, especially for large emittances and momentum spreads. Even pulsed 60 kG quadrupole devices caused severe emittance growth for large emittances ($> 10 \pi \text{ mm-mr}$). However, if we are initially constrained to small momentum spreads and emittances, we should consider the option of installing the original 5Q36 triplet, especially if the lithium lens system is not ready.

REFERENCES

1. A. Garren and A.G. Ruggiero, *Precooler Lattice*, p Note #115 (Feb. 12, 1981).
2. K.L. Brown et al., *TRANSPORT*, CERN 73-16 (1973).
3. T. Vsevolozhskaya, *The Chromatic Aberration of Lenses with Large Angular Acceptance*, unpublished report.
4. E.P. Colton, *Antiproton Transport to Precooler*, p Note #86 (1980).
5. K.L. Brown et al., *DECAY TURTLE*, CERN 74-2 (1974).

FIGURE CAPTIONS

- Fig. 1 4.5 GeV \bar{p} beam phase spaces at injection for $\epsilon = 5.0 \pi \text{ mm-mr}$ for 5Q36 collector.
- Fig. 2 Phase spaces for $\Delta P/P = \pm 2.0\%$ for both lithium lens and pulsed quadrupole collectors, $\epsilon = 5.0 \pi \text{ mm-mr}$.
- Fig. 3 Phase spaces for $\Delta P/P = \pm 2.0\%$ for both lithium lens and pulsed quadrupole collectors, $\epsilon = 10 \pi \text{ mm-mr}$
- Fig. 4 Phase spaces for $\Delta P/P = \pm 2.0\%$ for both lithium lens and pulsed quadrupole collectors, $\epsilon = 20 \pi \text{ mm-mr}$

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p Note #120Table 1. 4.5 GeV \bar{p} Collectors

Element	Length (cm)	Aperture (cm)	Gradient (T/m)
<u>A. Lithium Lens</u>			
Drift	15.0		
Lithium Lens	10.0	1.0	967.9
Drift	15.0		
<u>B. Pulsed Quadrupoles</u>			
Drift	7.5		
Q1 (HFQ)	10.0	1.0	600.0
Drift	4.0		
Q2 (VFQ)	20.47	2.0	-300.0
Drift	7.0		
Q3 (HFQ)	33.47	4.0	+150.0
Drift	10.0		
Q4 (VFQ)	39.12	5.0	-120.0
Drift	12.0		
Q5 (HFQ)	23.33	6.0	100.0
Drift	100.0		
<u>C. 5Q36 Quadrupole Triplet</u>			
Drift	50.0		
Q1 (HFQ)	95.25	6.25	19.0
Drift	42.33		
Q2 (VFQ)	95.25	6.25	-19.0
Drift	42.33		
Q3 (HFQ)	95.25	6.25	9.531
Drift	100.0		

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Table 2. Final Sinelike Trajectories

Collector	S_x (m)	S_y (m)
Lithium Lens	0.20	0.20
Pulsed Quadrupoles	1.300	0.800
5Q36 Triplet	3.288	2.184

Table 3. Percent Transmission into $\beta = 10$ m Waists
for $\Delta P/P = \pm 2.0\%$ Rays

Emittance (mm-mr)	Maximum Angle (mr)	Collector		
		Lithium Lens	Pulsed Quadrupoles	Lithium Lens (No Scattering)
5 π	12.5	65.9	60.6	89.6
10 π	25.0	64.9	45.1	85.0
20 π	50.0	59.8	30.3	74.8

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1.5 GeV \bar{p} phase spaces $\frac{\Delta p}{p} = \pm 2.0\%$

AT PRECOOLER

LITHIUM LENS COLLECTOR | QUADRUPOLE MULTIPLET COLLECTOR

t = 0.60 | t = 0.30

	-20.000	-10.000	0	10.000	20.000,0UN	-10.000	0	10.000	20.000 TOTALS
1	-20.000	-10.000	0	10.000	20.000,0UN	-10.000	0	10.000	20.000 TOTALS
2	-4.750 TU	-4.750	1	1	211.2	11.22123	1	21	
3	-4.500 TU	-4.250	1	1	311.2	122444	1	24	
4	-4.250 TU	-4.000	1	1	324.1	2212411	1	26	
5	-4.000 TU	-3.750	1	1	1.1	1.1	1	1	1
6	-3.750 TU	-3.500	1	1	12 33112	16136431	1	38	
7	-3.500 TU	-3.250	1	1	12 34521	21234465	1	42	
8	-3.250 TU	-3.000	1	1	1.1	1.1	1	1	1
9	-3.000 TU	-2.750	1	1	1.1	1.1	1	1	1
10	-2.750 TU	-2.500	1	1	1.1	1.1	1	1	1
11	-2.500 TU	-2.250	1	1	1.1	1.1	1	1	1
12	-2.250 TU	-2.000	1	1	1.1	1.1	1	1	1
13	-2.000 TU	-1.750	1	1	1.1	1.1	1	1	1
14	-1.750 TU	-1.500	1	1	1.1	1.1	1	1	1
15	-1.500 TU	-1.250	1	1	1.1	1.1	1	1	1
16	-1.250 TU	-1.000	1	1	1.1	1.1	1	1	1
17	-1.000 TU	-750	1	1	1.1	1.1	1	1	1
18	-750 TU	-500	1	1	1.1	1.1	1	1	1
19	-500 TU	-250	1	1	1.1	1.1	1	1	1
20	-250 TU	-250	1	1	1.1	1.1	1	1	1
21	-250 TU	-250	1	1	1.1	1.1	1	1	1
22	-250 TU	-250	1	1	1.1	1.1	1	1	1
23	-250 TU	-250	1	1	1.1	1.1	1	1	1
24	-250 TU	-250	1	1	1.1	1.1	1	1	1
25	-250 TU	-250	1	1	1.1	1.1	1	1	1
26	-250 TU	-250	1	1	1.1	1.1	1	1	1
27	-250 TU	-250	1	1	1.1	1.1	1	1	1
28	-250 TU	-250	1	1	1.1	1.1	1	1	1
29	-250 TU	-250	1	1	1.1	1.1	1	1	1
30	-250 TU	-250	1	1	1.1	1.1	1	1	1
31	-250 TU	-250	1	1	1.1	1.1	1	1	1
32	-250 TU	-250	1	1	1.1	1.1	1	1	1
33	-250 TU	-250	1	1	1.1	1.1	1	1	1
34	-250 TU	-250	1	1	1.1	1.1	1	1	1
35	-250 TU	-250	1	1	1.1	1.1	1	1	1
36	-250 TU	-250	1	1	1.1	1.1	1	1	1
37	-250 TU	-250	1	1	1.1	1.1	1	1	1
38	-250 TU	-250	1	1	1.1	1.1	1	1	1
39	-250 TU	-250	1	1	1.1	1.1	1	1	1
40	-250 TU	-250	1	1	1.1	1.1	1	1	1
41	-250 TU	-250	1	1	1.1	1.1	1	1	1
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44	-250 TU	-250	1	1	1.1	1.1	1	1	1
45	-250 TU	-250	1	1	1.1	1.1	1	1	1
46	-250 TU	-250	1	1	1.1	1.1	1	1	1
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51	-250 TU	-250	1	1	1.1	1.1	1	1	1
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64	-250 TU	-250	1	1	1.1	1.1	1	1	1
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66	-250 TU	-250	1	1	1.1	1.1	1	1	1
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142	-250 TU	-250	1	1	1.1	1.1</			